Electromagnetic Theory II: Homework 6

Due: 16 February 2021

1 Cylindrical magnetic material

An infinitely long cylindrical material has radius R. A free current flows along the length of the cylinder. The current density given in cylindrical coordinates, is

$$\mathbf{J}(\mathbf{r}') = \alpha s' \hat{\mathbf{z}}$$

where $\alpha > 0$ is a constant. The material has susceptibility χ_m.

a) Let I_{free} be the total free current flowing along the cylinder. Determine an expression for α in terms of I_{free}.

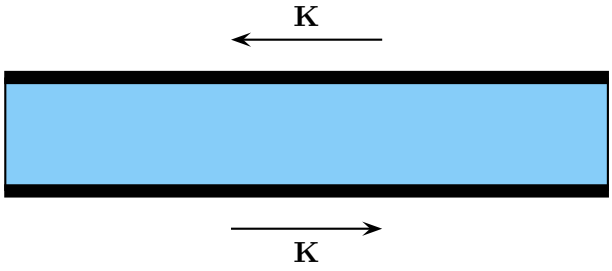
b) Determine the magnetic field everywhere in terms of R, χ_m and I_{free}.

c) Determine the bound surface and volume current densities in the material. Sketch these.

d) Do the bound currents have any affect on the field outside the material? Explain your answer.

2 Slab of linear magnetic material

Two infinite sheets of material carry surface currents with the same surface current density with magnitude K but in opposite directions. An infinite slab of linear magnetic material with permeability μ is placed between these. The situation, as viewed from the side, is as illustrated.



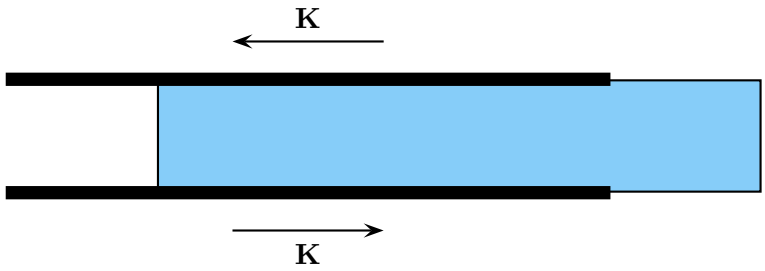
a) Suppose that the material were absent. Determine the direction of the magnetic field between the sheets. Use this to describe the direction of the magnetization and the direction of the bound currents.

b) Determine the auxiliary field at all locations. If you use Ampère's law, provide an argument that constrains the direction of the auxiliary field first.

c) Determine the magnetic field at all locations.

d) Determine an expression for the bound current densities in the material.

Consider a finite version of this in which the material is partially inserted into the gap between the plates



e) Without calculating all the fields and by using qualitative reasoning about the interactions between the currents in the sheets and the material describe the direction of the net force exerted on the material by the sheets if the material is: i) silver and ii) platinum. In each case you can assume that there is an thin insulating layer between the sheets and the material. *Hint: you will have to look and use the susceptibility of the materials.*